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Scoping Instruction at the Combined Arms and Services Staff School

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NOTICES

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14. ABSTRACT *(Maximum 200 words)*:

The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI), Fort Leavenworth Research Unit, regularly conducts research and evaluation in support of the Command and General Staff College. ARI provided the Combined Arms Services Staff School (CAS3) with program development by providing curriculum evaluation for the Scoping Program of Instruction (POI). The Scoping POI deals specifically with students' ability to identify major factors of a problem, make reasonable rapid rough estimates of the effects of the factors, purposely neglect small or insignificant factors, and develop a quick overall gross level "picture" of the problem. Examination of this curriculum for CAS3 and enlisted populations show enhanced scoping performance following instruction.

15. SUBJECT TERMS

Scoping Problem solving
Estimation Decision making

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SCOPING INSTRUCTION AT THE COMBINED ARMS AND SERVICES STAFF SCHOOL

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Scoping Instruction at the Combined Arms and Services Staff School

Introduction

Army Research Institute, Ft. Leavenworth, has conducted a long-term program of research in group problem solving at the Combined Arms and Services Staff School (CAS^3). The nine-week course offered by the Command and General Staff College (CGSC) at Fort Leavenworth is taken by all U.S. Army officers when they are captains. This research has focused on situations in which problem solving groups subdivide into smaller groups that must coordinate and work interdependently to solve a larger problem (Lussier, Solick & Keene, 1992; Lussier, 1992). One goal of the research is to identify skills which are important in group problem solving and which appear to offer significant challenge to the students.

A commonly perceived deficit of groups at CAS^3 is an inability to efficiently "scope the problem," i.e., identify major factors, make reasonably rapid rough estimates of the effects of these factors, neglect small or insignificant factors, and develop a quick overall gross level "picture" of the problem. To alleviate the deficit, a block of instruction, called "Scoping" was developed which explains the concept of scoping, identifies scoping techniques, and includes two scoping exercises. The details of the program of instruction (POI), the instructor notes, are presented in Appendix A of this report. The major goals of the instruction are to introduce the concept of scoping, to encourage students to use this thinking skill, and to develop increased facility.

Method

The research described in this report portrays two samples. First, CAS^3 students who received the scoping instruction are compared with a group of different CAS^3 students who had not yet received the instruction. Second, enlisted soldiers' related performances are compared before and after they received the scoping instruction. These analyses are made in order to determine if the scoping curriculum effects student performance on an estimation exercise. The first sample comprised 48 CAS^3 students. The second sample comprised 19 enlisted soldiers.

<u>CAS^3 student independent sample</u>. The Scoping POI was developed to enhance the problem solving skills of CAS^3 students and is presented as a portion of the initial problem solving module. The scoping curriculum is a mandatory portion of the CAS^3 course of instruction and is presented as Day 3 of the 9-week course.

Forty-eight captains were selected from CAS^3 classes to participate in analysis of the impact of the scoping curriculum. Half of the students received a test of scoping prior to instruction and the other 24 students received the test after the block of instruction. The scoping test involved estimating the number of beef cattle in the United States. Appendix B describes the test and the method of scoring in more detail.

The instructor introduced scoping as a critical skill for problem solving and then defined its uses. An example was then given for students to plan a solution. The instructor walked the students through the steps of mental planning, calculations, and checking for reasonableness. Next, the students received a military problem and were asked to mentally develop a plan. The

plans were openly discussed as students encountered potential difficulties. Students were asked to make estimations and to look back at the reasonableness of their answers. A final measure of scoping skill was administered.

Enlisted repeated measures sample. A second sample of soldiers was also used to examine the curriculum's effectiveness. The enlisted group's sequence and content of instruction is similar to the program of instruction given the officer student group. The sequence for this group included an initial measure, the delivery of the program of instruction (minus a group problem) and the administration of a post-course measure upon completion of the instruction.
Nineteen soldiers in grades E-3 to E-6, all within the same MOS, were administered the scoping instruction with a pre-course and a post-course measure.

Two similar measures were developed and used to examine performance prior to and after instruction. One measure involved estimating the number of beef cattle in the United States. The other involved estimating the number of dairy cattle in the United States. Appendix B describes the measures and the method of scoring in more detail.

Ten soldiers received the cattle test as a pre-course measure prior to training. This measure was then used as the post-course measure for the remaining nine soldiers. Similarly, these other nine soldiers received the dairy test as their pre-course measure and the cattle test as their post-course measures. Mean and standard deviation of the independent scores for these measures were not significantly different, $t(21,23)=.883$. These measures are considered similar for the purpose of examining participant performance differences independent of instruction.

Results

The most pronounced effect of the curriculum was the increased willingness of all participants to engage in the scoping skill. In each group, participants' initial rate of attempt was low (58% of CAS^3 students, 32% of enlisted participants) for the measures given prior to the scoping instruction. Upon completion of the instruction, rate of participant attempts rose significantly, X^2 (1,5.17), p=.023, for the CAS^3 student sample and McNemar Z (19, 11,2), p=.0005, for the enlisted sample (McNemar Change Test discussed in Siegel & Castellan, 1988). CAS^3 students' rate of problem completion rose to 88% and the enlisted participants' rate of completion rose to 90%.

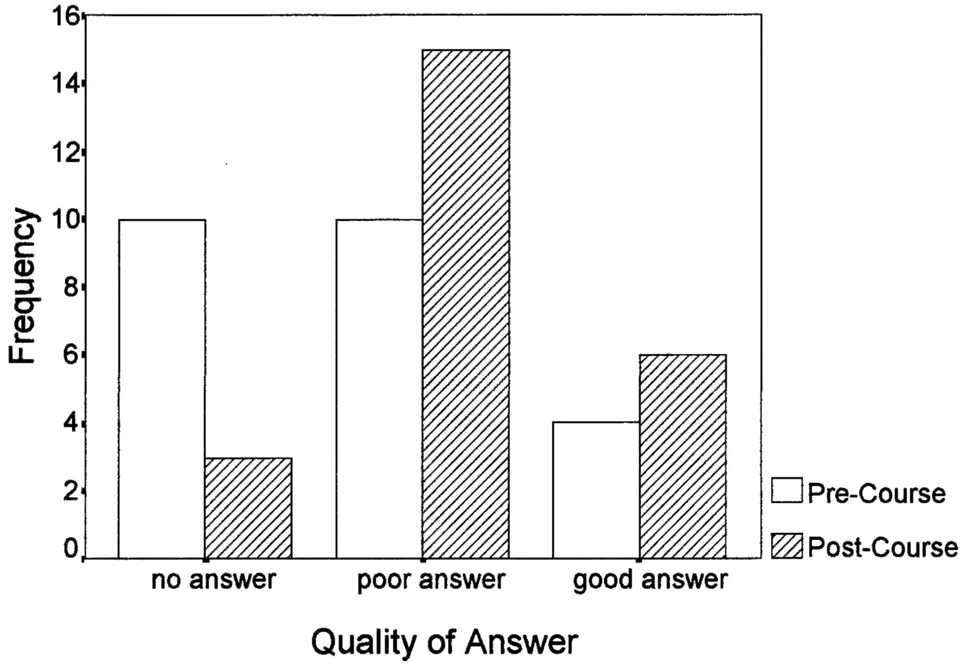

Figure 1. CAS[3] independent sample. Frequency of responses categorized into no answer, poor answer, and good answer for precourse group (n=24) and postcourse group (n=24).

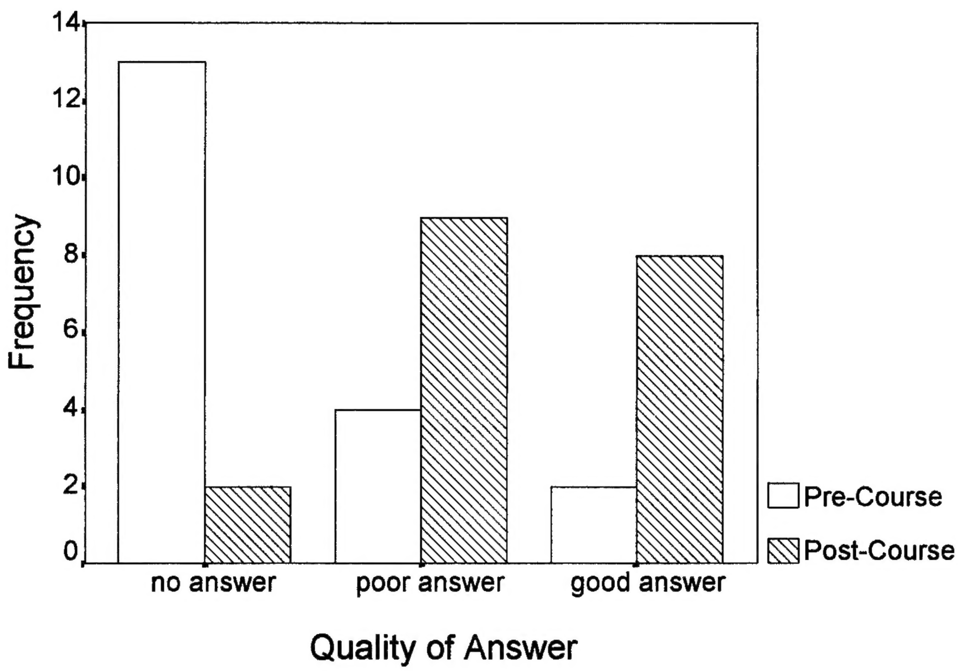

Figure 2. Enlisted repeated measures sample. Frequency of responses categorized into no answer, poor answer, and good answer for precourse group (n=19) and postcourse group (n=19).

Table 1 Error scores for participants with and without scoping instruction

	With			Without		
	M	SD	n	M	SD	n
CAS^3 captains	53.96	11.60	21	50.91	7.75	14
Enlisted participants	48.87	8.95	16	53.33	12.75	6

Closer examination of scores shows very poor numeric answers to greatly effecting the analysis. Little knowledge of cattle weight or dairy cow production or lack of motivation to examine the measured problem may have attributed for answers whose values are clearly outliers. As shown in table 1, inclusion of these scores induce variable means and SDs when they are considered for numeric score comparison. All scores are retained for analyses although outliers exist. The measure and therefore the analysis does not sufficiently differentiate between wild guesses and scoping estimates. Figures 1 and 2 illustrate the use of categorical and ordinal classification (i.e. "no answer," "poor answer," and "good answer") and subsequent nonparametric analyses lessen the impact of large error scores.

However, when solutions are classified with No Answer scored as failures instead of as missing data, scores show significant improvement, Wilcoxson-Mann-Whitney Test, U (20.25,28.75)=186, p=.0168, for the CAS^3 sample and Wilcoxon Matched-Pairs Signed-Ranks Test, p=.0014, for the enlisted sample (both tests described in Siegel & Castellan, 1988). When No Answer solutions are treated as missing data, both groups again obtained increased Good solutions following the scoping curriculum skills training. The improvement, however, is not statistically significant for either group, t (33,35)=.86, p=.179 for the independent CAS^3 sample and t (5,6 pairs)=.97, p=.187 for the enlisted repeated measures sample.

Discussion

Scoping trains soldiers to determine high impact aspects of the problem, use estimation and combine similar or less significant portions of the problem, identify irrelevant information, and bracket best and worst case scenarios. With these skills, soldiers generalize to other problems they encounter and are more willing to think through a problem that previously seemed insoluble.

Although scoping training assisted students in correctly solving problems, its greatest impact is its feature of encouraging soldiers to engage in problem solving given scoping requirements. Without training, many individuals cease problem solving efforts at the first sign of difficulty or ambiguity. Problems requiring only moderate effort may be dismissed as too difficult before they are explored.

Pfeiffer, Feinburg, and Gelber (1987) describe five attitudes needed for effective problem solving; a) an attitude of inquiry, b) an attitude of flexibility and open-mindedness, c) a positive belief in ones own problem solving efficacy, d) a perspective recognizing problems as challenges or opportunities to learn, and e) willingness to examine problems in a larger contexts, with increased perspective. The scoping curriculum is related to increased problem solving attempts and skill. It produces increased willingness to examine and then attempt solutions to problems. A positive perception of problems' resolution as well as a subsequent increase in problem solving behavior may contribute to increased problem solving ability.

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COMBINED ARMS AND SERVICES STAFF SCHOOL
F121 Staff Techniques Exercise
STAFF LEADER NOTES
Encl 1 Scoping

F121-1 Problem Solving

DAY 3 Phase II CAS3 Date: January 1993
DAY 2 Phase II RC-CAS3

NOTES

SLNOTE: The scoping part, encl 1 to staff leader notes, was written to be taught at this point in the problem solving lesson. Depending on SL preference and time available it could be moved to--

--the end of the DAY 3 problem solving lesson, or

--discussed at a separate time, e.g., before VARWARS.

PRESENTATION

Scoping, also known as estimation, rough estimation, or gross estimation, is a critical skill for effective problem solving. It is essential that you understand this skill and use it in your problem solving.

Most of you have used scoping or estimation before, some of you by instinct and without method. What we want to do is show you the practical uses of scoping in problem solving and give you some techniques to use. Proficiency and clear understanding of scoping will come only if you practice these skills, learn when to use them, and learn when a particular technique is most appropriate for a situation.

NOTES

DEFINITION OF SCOPING

Scoping, also known as rough or gross estimation, is a quick procedure used to get an approximate answer.

USE OF SCOPING

1. Error checking. Before doing any detailed (especially numerical) calculations, it is best to arrive at a quick approximate (ballpark) answer. If the result of the detailed calculation procedure is not close enough to the scoping estimate, error check both procedures to reconcile the difference.

2. Exploration of Potential COAs. Scoping provides a perspective on the entire problem. When time permits, it is best to evaluate all possible courses of action (COAs). In some complex situations, there are an unlimited number of solutions and detailed analysis of each solution is very time consuming. Scoping can indicate which possible COAs are not feasible and which COAs have enough merit to warrant a more detailed analysis.

3. Group Planning. When a group works on a problem concurrently, such as in battle staff planning, scoping provides estimates for other group members to work with while the detailed analysis continues. When better answers arrive, they can be substituted for the estimates. This allows a complex plan with several components to be developed concurrently, yet maintains an integration of the parts.

NOTES

We are going to describe several techniques to help you scope problems and show examples of how to apply them. Knowing when to use each technique or a combination of techniques is learned through practice and will vary with each problem solving situation.

SCOPING TECHNIQUES

1. The procedure to follow in any scoping situation is:

<u>First</u>: Make a mental plan.

Determine how you intend to logically proceed.

Think through the procedure without doing calculations.

<u>Second</u>: Do the calculations required.

<u>Third</u>: Look back to error check.

Does the estimate seem reasonable?

Did you ignore any critical factors?

2. Look for key, high-impact factors and concentrate on them. Lump minor factors together and disregard irrelevancies and insignificant factors.

--What elements are essential or determine the bulk of the problem? Concentrate your effort on these issues.

--What elements influence the outcome but can generally be lumped together and factored into the estimate as one rather than many computations?

--Identify irrelevant or negligible factors and drop them from the estimate; however, do not forget to consider them in the final solution.

3. Consider what a solution or estimate should look like. What does the problem ask for? In what terms will the answer be expressed? Often the question or problem statement will tell you.

4. Round numbers to the nearest relevant value. Estimates don't require exactness. Do you need values to the nearest tens or to the nearest millions? Rounding can help avoid "order of magnitude" errors and misplaced decimal points.

5. Depending on the situation, you may want to make a "best case" or "worst case" estimate, using maximum and minimum values. Sometimes you may want to do both to bracket the solution.

6. Be aware of the direction calculations should have on your figures. For example, when you apply some effect do you expect it to increase or decrease the estimated amount?

7. If you are faced with complex calculations, solve the problem first with simple data; e.g., whole numbers instead of fractions, single digits instead of numbers in the thousands. Reduce the problem to steps to prove the procedure, then apply the procedure to your actual situation.

SL NOTE: Item 8 can be used as a SL question to generate discussion and to lead into the harder practical exercises.

NOTES

8. When you don't know some value, do not simply give up. You can often come close by using values you do know. How many dogs in New York City? Who knows, but if you know the population of New York City is 8 million, you can guess that a percentage are dog owners and get in the ballpark.

SL NOTE: At this point, we will use two practical exercises to illustrate the points and techniques. They are presented in the recommended order, but you may wish to reverse the order of presentation. The problem to be scoped is stated. It is recommended that you:

a. Give the students the problem.

b. Let students try individually to make a mental plan (step 1).

c. Use the model provided to discuss the mental planning step.

d. Let students try individually to make the calculations (step 2).

e. Discuss the calculation step.

f. Conduct the error checking (step 3) as a group.

The step-by-step solution provided is a model only; it is not the only correct solution. Other procedures and solutions may be just as valid.

Now, let's look at a problem.

NOTES

EXERCISE 1. GAS TAX

The Problem: A suggestion is made to cut the national debt (about $4 trillion) by adding a gasoline tax of 10 cents per gallon which would increase by 10 cents a year to 50 cents per gallon in the fifth year. About how much money would the tax raise in the entire 5-year period?

Step 1. Make a Mental Plan.

Before doing any numeric calculations, make a mental plan of how you are going to accomplish the estimate. Think through the process without using numbers. The plan will tell you what quantities you need to know in order to complete the scoping. Then try to make reasonable estimates of these factors.

SL NOTE: Give students 2 to 3 minutes to make their mental plans then discuss this step. A model plan is given below. Note that this is only one possible solution, not the only solution.

a. Find the average amount of gas used by one car in 1 year:

Estimate: 10,000 miles driven per year; 20 miles per gallon.

b. Gallons/year x $.10 = first year tax per car.

c. First year tax = 1 x 1st year tax

Second year tax = 2 x 1st year tax

Third year tax = 3 x 1st year tax

Fourth year tax = 4 x 1st year tax

Fifth year tax = 5 x 1st year tax

Total tax = 15 x 1st year tax

Total tax per car = 15 x 1st year tax per car.

d. Cars in US = Population of US x percentage of car owners.

Population of US is approximately 250 million, so 200 million cars is a high estimate. However, using 200 million cars gives a maximum value for total revenue and compensates for the non-car uses of gasoline that are being ignored.

e. Cars in US x tax per car = total tax collected.

f. Compare total tax to national debt.

Step 2. Make the Calculations.

The next step in scoping is to make the calculations based on the mental plan.

SL NOTE: Give the students 2 to 3 minutes to make their calculations. For the values estimated above the calculations are:

--10,000 miles per year/20 mpg = 500 gallons per year.

--500 gallons per year x $.10 = $50 per year for average car.

--$50 x 15 = $750 per car total tax.

--$750 x 200 million cars = $150 billion total tax over 5 year period.

---$150 billion tax revenue is less than .04, i.e., 4 percent of a $4 trillion national debt.

NOTES

Step 3. Look Back.

Is the estimate reasonable?

Have you neglected major sources, e.g., truckers and taxicabs drive much more than 10,000 miles per year. Heavy equipment gets much less than 20 miles per gallon. Other gasoline users could be lawn mowers, boats, tractors, etc. In the model above all these factors were lumped together and ignored. Does overestimating the number of cars at 200 million compensate for ignoring many small factors?

Will people react to the tax by decreasing driving miles and buying more fuel-efficient cars? How much could this reduce revenue?

Overall, how far off can the estimate be? Could the gas tax revenue wipe out 5 percent of the national debt? 10 percent?

EXERCISE 2. SUPPLY PROBLEM

SL NOTES: Pass out information sheets and give the following instructions

Step 1. Make a Mental Plan.

Before calculating any numbers, make a mental plan of how you are going to accomplish the estimate. Look at the information sheets. Understand what you are being asked for and decide what you are going to do. Take a few minutes to understand the problem and plan the estimate.

<u>SL NOTES</u>: Wait 3 to 5 minutes then discuss the plan. The main elements are:

--Unlike the gas tax example, many figures are provided. Many students have no difficulty doing rough scoping when they are estimating numbers (as in the gas tax exercise), but have difficulty rounding and estimating when they have many supposedly exact figures.

--Much of the information on the sheet is irrelevant to the problem.

--Some students may have been overwhelmed by the amount of data and unable to even begin to form a mental plan. Recall the technique discussed previously. What does the problem ask for? In what terms is an answer expressed? Here, number of truck companies is asked for. Then, look for what factors impact on truck requirements--what do you need to know to get the number of truck companies? Here, truck companies equate to a haul capacity, given in tons/day. Thus what you need is a haul requirement in tons/day.

--The basic plan is to estimate total tons per day the corps consumes then see how many truck companies are required to handle that tonnage.

--POL must be handled separately.

NOTES

--Some consumption factors (non-Class V) are given in pounds per soldier per day. These can be handled as follows: Total number of soldiers pounds/soldier/day = pounds/day haul requirement. Then convert to tons/day.

--Class V need is given for a division in tons/day. Calculate four divisions and a separate brigade. Add the Class V tonnage for corps.

Step 2. Make the Calculations.

Take a few minutes to make the calculations. Be quick and try not to make major "decimal point" errors. Round off and use gross estimation as much as possible.

SL NOTES: Wait 3 to 5 minutes then discuss the quick calculation process. One possible procedure:

a. Estimate total number of troops.

--Four divisions x 16,500 per division is 66,000 troops.

--Round up to 70,000 for the separate brigade.

--Double to 140,000 to consider the 1 to 1 ratio of corps troops.

b. Estimate non-Class V consumption.

--Each soldier needs 15 pounds/day of Class VIII + about 20 pounds/day of other supplies = 35 pounds per day.

NOTES

--35 x 140,000 = 4,900,000 pounds per day.

--Round to 5,000,000 pounds/day.

--5,000,000/2,000 = 2,500 ton/day.

c. Estimate Class V consumption.

Four divisions x 2,000 tons/division = 8,000 tons.

Corps Class V is 90 percent of divisions.

To make things easy allow the separate brigade the other 10 percent and just double the 8,000 tons/day to make 16,000 tons/day.

d. Calculate total tonnage required.

16,000 tons/day Class V + 2,500 tons/day other classes= 18,500 tons/day haul requirement.

e. Four medium truck companies can handle 18,000 tons a day (4,500 x 4). Therefore, four medium companies and one light company would be sufficient; five medium truck companies would provide a healthy margin.

f. Calculate POL requirement.

--POL requirement is 360,000 gallons per day per division.

--For speed and to reduce the size of the numbers used and the likelihood of error, work in million gallons rather than gallons.

--Round the division requirement down to about 1/3 of a million gallons.

4 x 1/3 = 1 and 1/3 million gallons for the four divisions.

--Round up to 1 1/2 million gallons to account for the separate brigade.

--Corps requires 50 percent or about 3/4 million gallons.

--Total requirement is 1 1/2 + 3/4 = 2 1/4 million gallons.

g. A medium POL company can haul 900,000 gallons per day. Two medium POL companies (900,000 gal/day each) will leave you short, but three will be more than sufficient.

h. Thus the final estimate is: five million truck companies, three medium POL companies, and one heavy truck company--required for outside cargo.

Calculations are easiest in medium truck companies. If desired, light truck companies could be substituted for medium truck companies at a ratio of about four or five light companies per medium company. Logisticians will consider that light companies would be useful to haul small load requirements more efficiently. A heavy truck company is required to haul loads that cannot be hauled by medium truck companies or to provide a specific capability, e.g., hauling tanks.

NOTES

If students could not do the calculations in 3 to 5 minutes they were probably trying for too exact a level of accuracy. An alternative (and perhaps superior) procedure to the one described is to ignore everything but Class V, and then round the estimate up to account for all the other classes. This could certainly be quicker and probably would not affect the final answer.

Step 3. Look Back.

--The final step to look back at what you've done. Is the estimate reasonable? If not, how far off could the rough estimation proceeds have taken you? 10 percent? 100 percent? More than one medium truck company?

--Have you overlooked any major sources of haul need or POL usage? (Some thoughtful students might think of water which has not been considered.)

--Notice that the non-Class V portion was relatively small so the rough estimates arrived at do not impact much. Focus the error check on the big-impact item, Class V.

--An exact calculation of the factors given would have taken much longer and would have given values of 18, 623 tons/day and 2,295,000 gallons of POL. In this case, the quick estimates were just as useful as the detailed ones. In fact they were probably more useful because they arrived sooner.

Scoping Problems

1. U.S. Cattle -

Most cattle raised for beef for the Unites States' 248,239,000 consumers are sold to feeder lots when they are yearlings. A small percentage are slaughtered around one year of age to produce veal. Most, however, are held at the feeder lots for another year and slaughtered when they weigh from 900 to 1300 lbs. on the hoof, depending on the breed. Estimate the total number of beef cattle currently in the United States. Try to work from an estimate of total beef consumption but remember that the entire population of cattle cannot be slaughtered in a single year. Show work below.

2. U.S. Milk Cows

Dairy production is the second largest principle farm commodity in the United States. With a US population approaching 250,000,000, dairy marking receipts exceed those of corn. A dairy farm in the midwest may have 60 or more cows, but a dairy farm in Florida or California may have 500 or more. These dairy cows are normally milked twice a day. Try to work from a notion of total dairy consumption to estimate the total number of milk cows currently in the United States. Show work below.

***Solutions** - approximately 100,000,000 cattle and 50,000,000 milk cows.*

All scores are transformed to T scores from the logarithm of the absolute ratio of differences from the correct answer for each problem. For categorical classification, "poor answers" differed more than three multiples, less or greater, from "good answers."